Risk Management of Monitored Natural Attenuation

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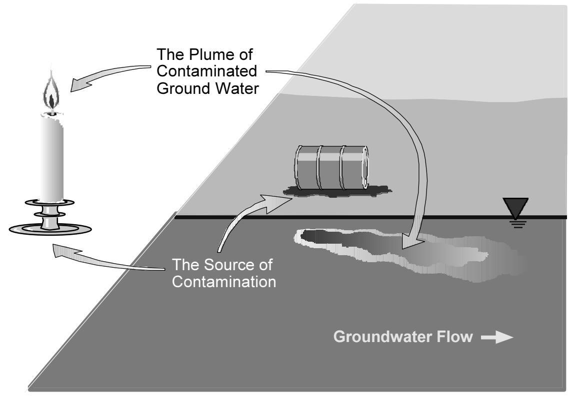


Benefits of Source Control

Case study:

Characterization and Monitoring Before and After Source Removal at a Former Manufactured Gas Plant (MGP) Disposal Site

EPRI TR-105921 Final Report Jan 1996

Benefits of Source Control

Source Area- 1/4 acre

Depth of Contamination- 0 to 20 feet

Volume of Contamination- 96,000 cubic yards

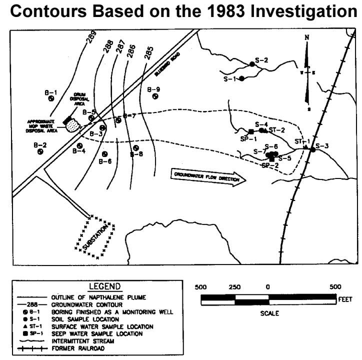
Water Table- 7 feet

Geology- 20 feet of sand over silty clay

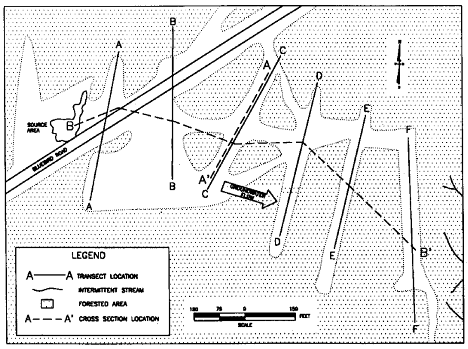
Benefits of Source Control

Costs for remedy $3,087,000	
site work	**37%**
soil transportation	**34%**
soil treatment	**24%**
waste water disposal	**5%**

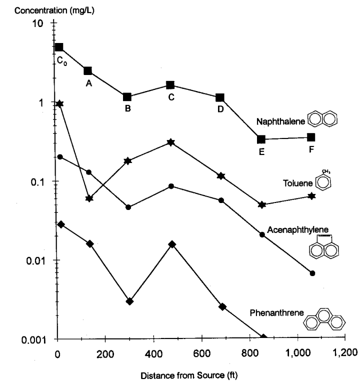
Estimated Groundwater Naphthalene Plume and Groundwater Contours Based on the 1983 Investigation



Location of Downgradient Geological Cross Sections

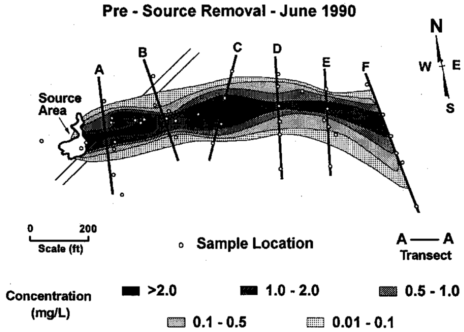


Centerline Groundwater Concentrations



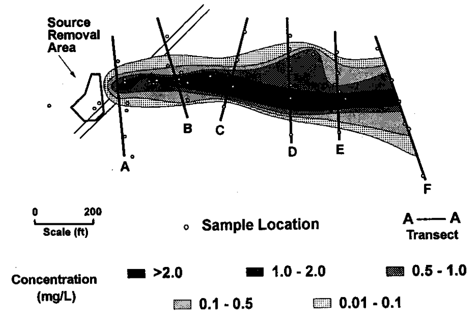
Naphthalene Groundwater Plume in 1990 and 1991
Areal View

Pre - Source Removal - June 1990



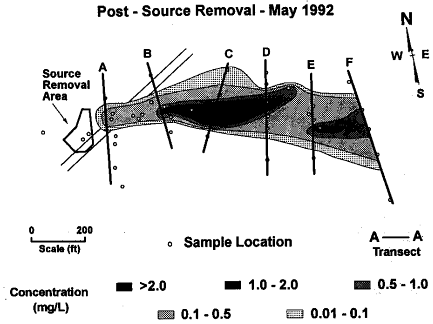
Naphthalene Groundwater Plume in 1990 and 1991
Areal View (Cont'd)

Post - Source Removal - November 1991



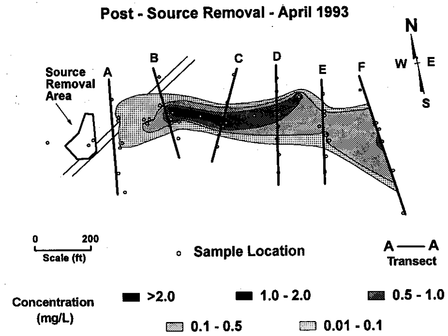
Naphthalene Groundwater Plume in 1992
Areal View

Post - Source Removal - May 1992

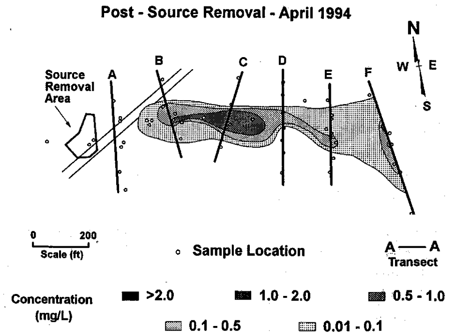


Naphthalene Groundwater Plume in 1993
Areal View

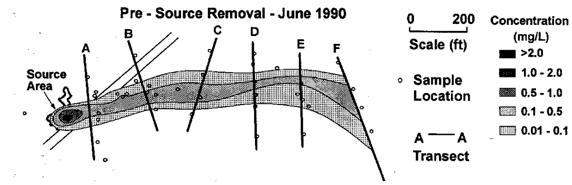
Post - Source Removal - April 1993



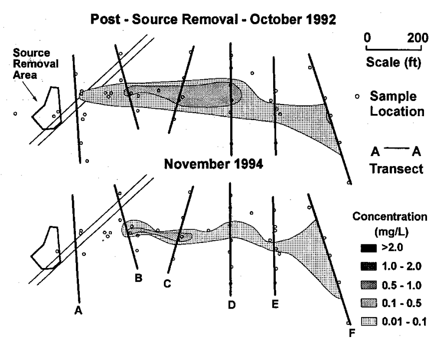
Naphthalene Groundwater Plume in 1994
Areal View



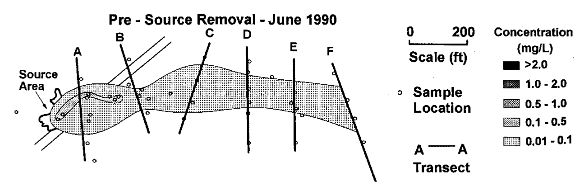
Toluene Groundwater Plume
Areal View



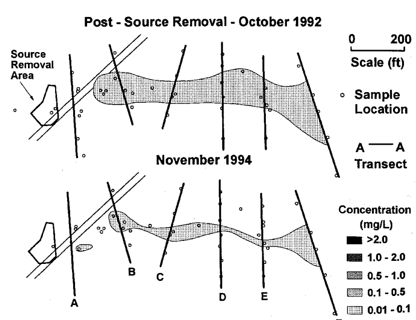
Toluene Groundwater Plume
Areal View (Cont'd)



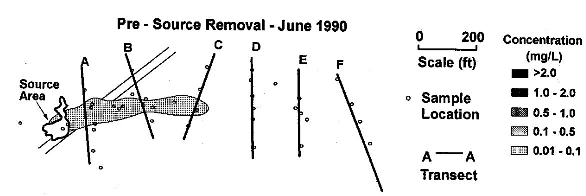
Acenaphthylene Groundwater Plume
Areal View



Acenaphthylene Groundwater Plume
Areal View (Cont'd)

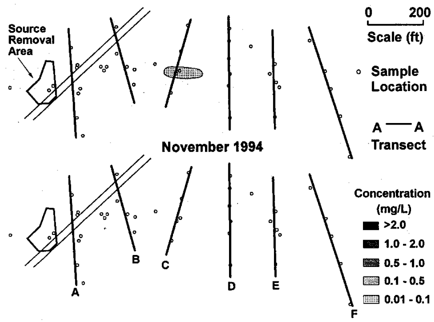


Phenanthrene Groundwater Plume
Areal View



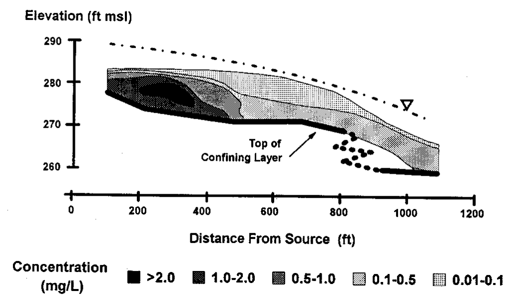
Phenanthrene Groundwater Plume
Areal View (Cont'd)

Post - Source Removal - October 1992



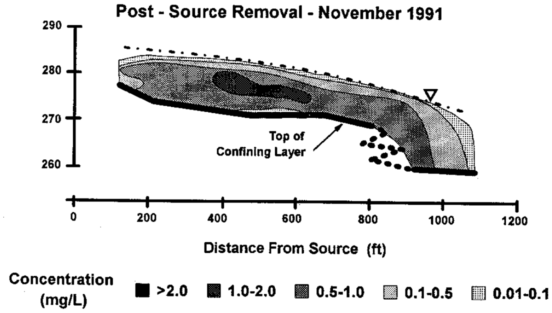
Naphthalene Groundwater Concentrations in 1990 and 1991
Cross-Sectional View

Pre - Source Removal - June 1990



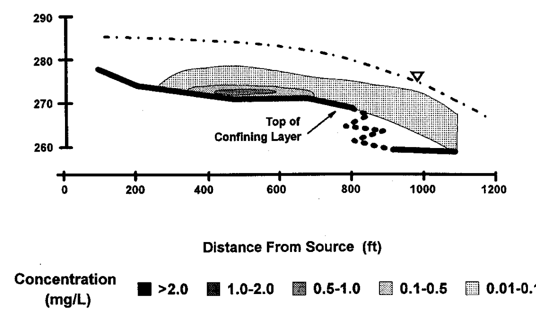
Naphthalene Groundwater Concentrations in 1990 and 1991
Cross-Sectional View (Cont'd)

Post - Source Removal - November 1991

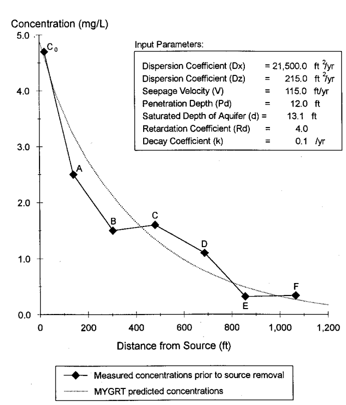


Naphthalene Groundwater Concentrations in 1994
Cross-Sectional View

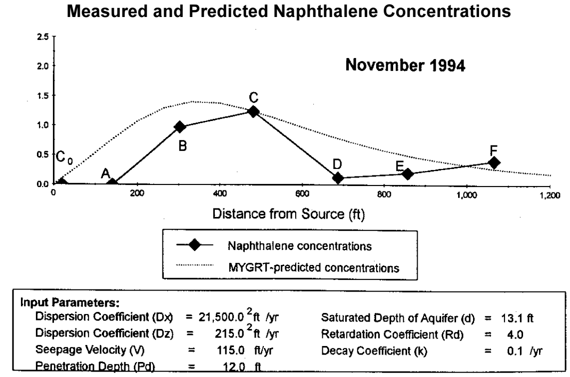
November 1994



Measured and MYGRT-Predicted Naphthalene Concentrations in Groundwater



Measured and Predicted Naphthalene Concentrations



Benefits of Source Control

After source removal, the aquifer cleaned up from the front end to the tail end.

The benefit moved faster than the average seepage velocity. The whole plume cleaned up, not just the front end.

Plume projected to reach NYDEC Drinking Water Standard for Naphthalene by 2030.

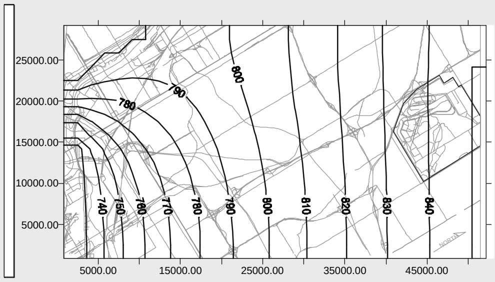
Large Chlorinated Solvent Plume

Natural Attenuation Model Study
Calibrated to Long Term Monitoring
Data

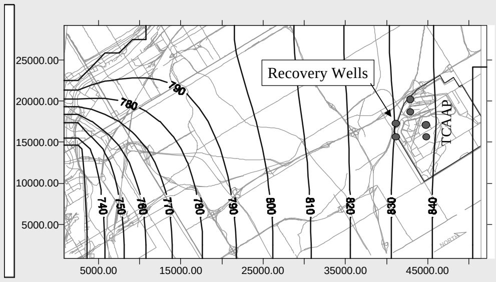
Basic Model Input Parameters

- Hydraulic Conductivity = 280 ft/day
- Thickness = 190 feet including unconsolidated sand and fractured bedrock aquifers
- Effective porosity = 0.20
- Retardation factor = 1.0
- Start time for model approximately 1940
- Model domain x = 53,000 feet y = 30,000 feet
- Pumping from recovery wells active for all simulations according to published rates. Pump and treat began in 1989

Simulated Static Water Level



Simulated Water Level With
Active Recovery Wells



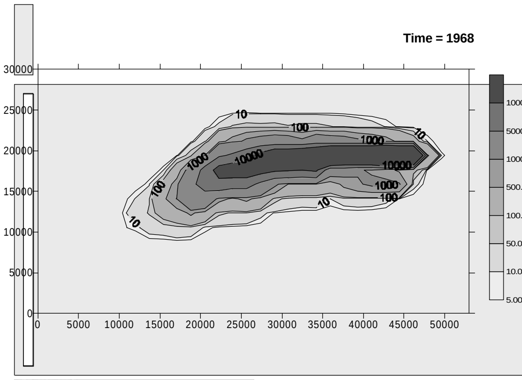
Flow Model Conclusion:

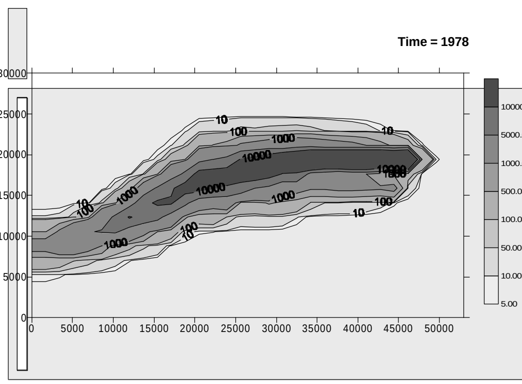
- Regional flow appears to be strongly influenced by river navigation system causing flow to converge southeast
- Recovery wells do no appear to modify flow patterns significantly on a regional scale

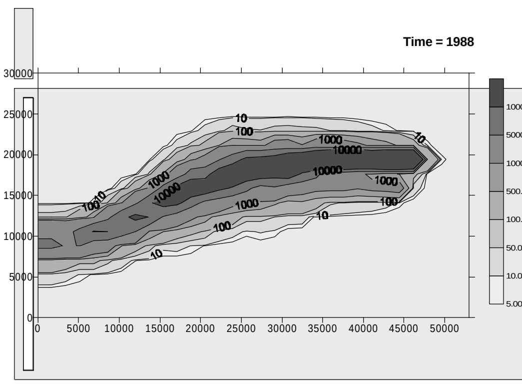
Initial Simulation:
No Source or Dissolved Decay

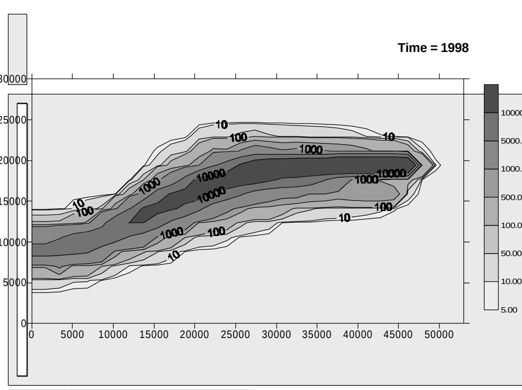
- Source 1:
  - Located: North half of site
  - Active from beginning of model
- Source 2:
  - Located: South half of site
  - Active from 1960

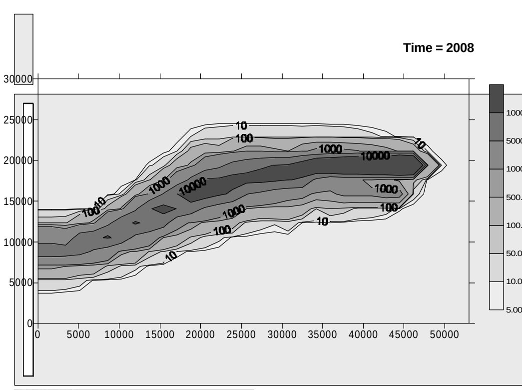
No Decay Simulation









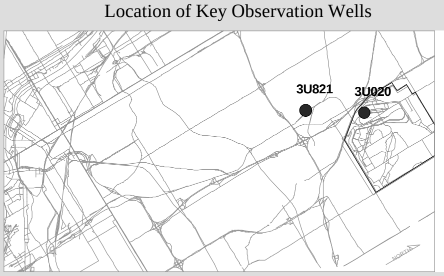


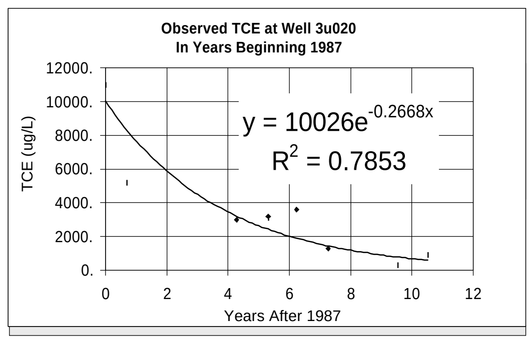
No Decay Simulation Conclusions

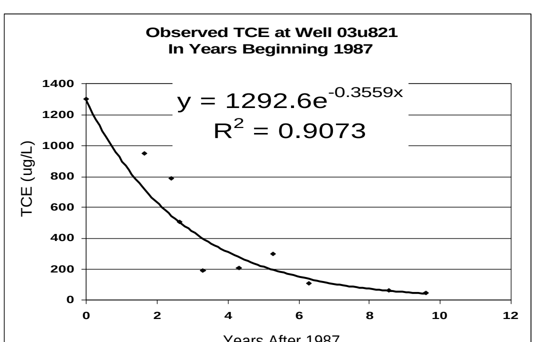
- Contaminants are predicted to reach the river with no natural degradation or source removal
- Time to reach river ~34 years
- Steady state reached in ~46 years

Addition of Source Decay

Location of Key Observation Wells



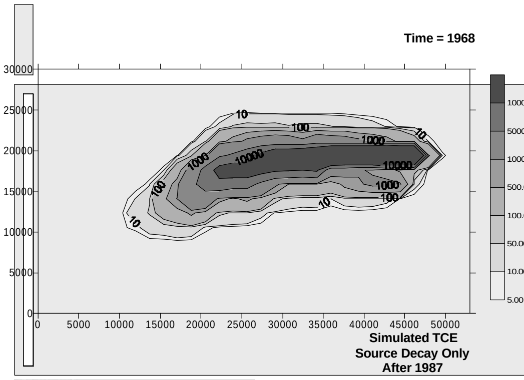


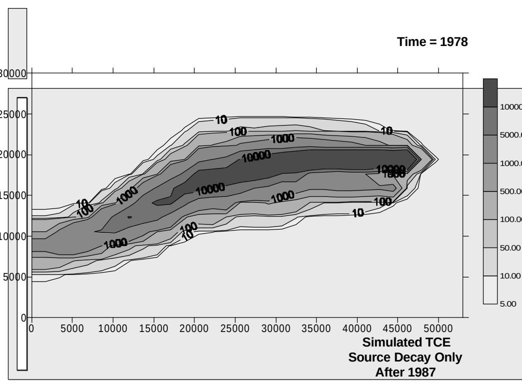


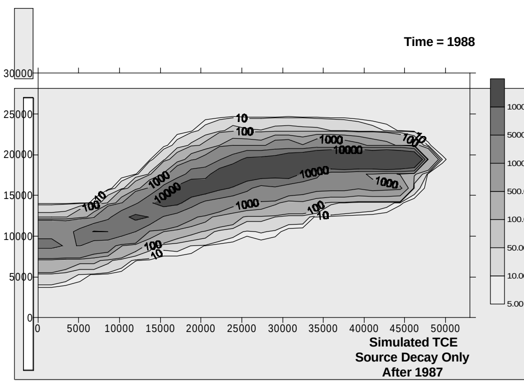
Second Simulation:
Addition of Source Decay

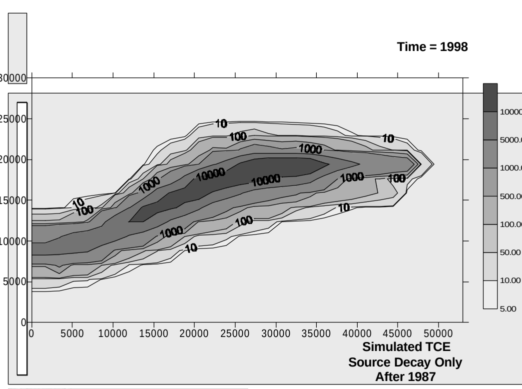
- Source decay fit to actual decline in concentrations in monitoring wells over time
- Source decay added according to first order kinetics with k = 0.25 per year
- Sources held constant till 1988 after which decay was allowed

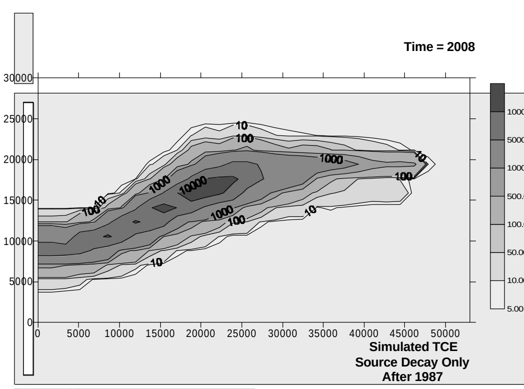
Source Decay Simulation











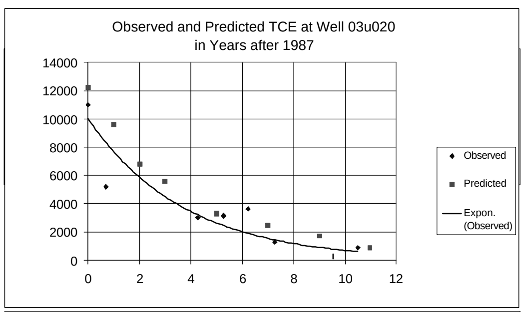
Source Decay Simulation Conclusion:

- Without dissolved phase natural attenuation, TCE still would be predicted to reach the river even though pumping and source decay/removal are active
- Plume duration is ultimately controlled by source discharge of TCE to the aquifer from the source area

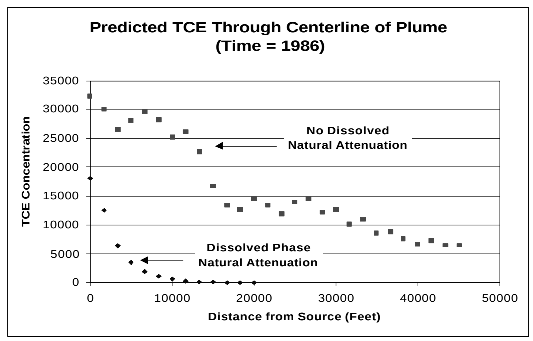
Third Simulation:
Addition of Intrinsic Bioremediation

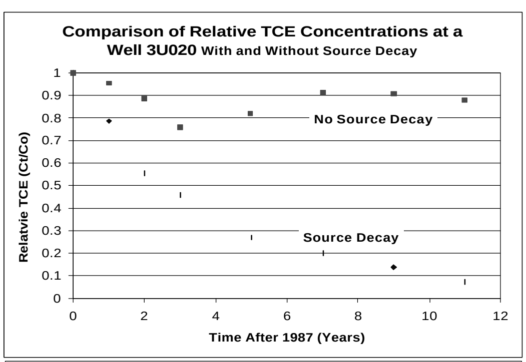
- Bioremediation added at k = 0.35 per year or half life = 2 years
- Rates applied throughout the time domain of the simulation
- Pumping and source decay still active

Comparison of Simulation Results



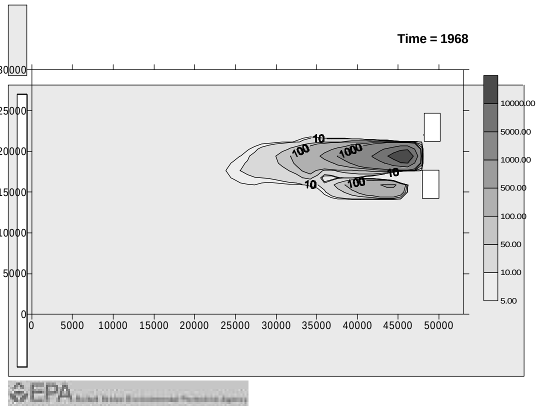
Go to Location Map





Go to Location Map

Source and Dissolved Phase Decay Simulation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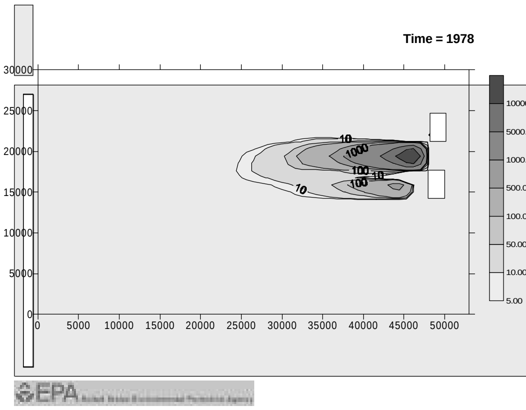
50.00
10.00
5.00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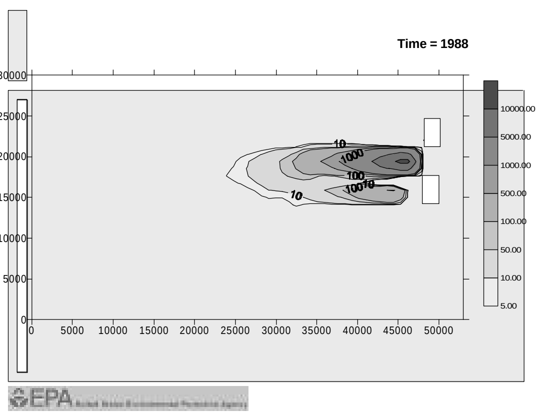
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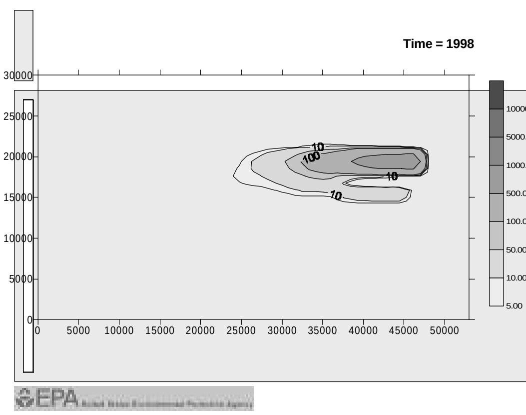
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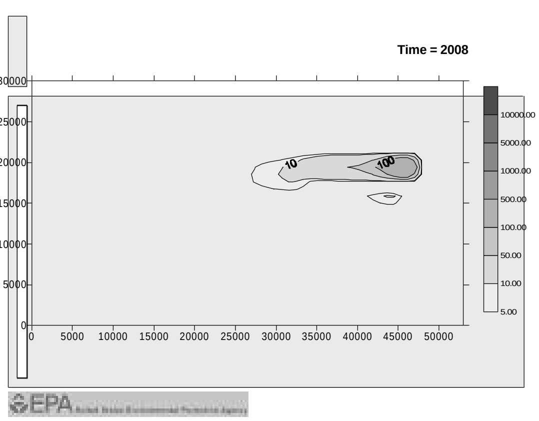
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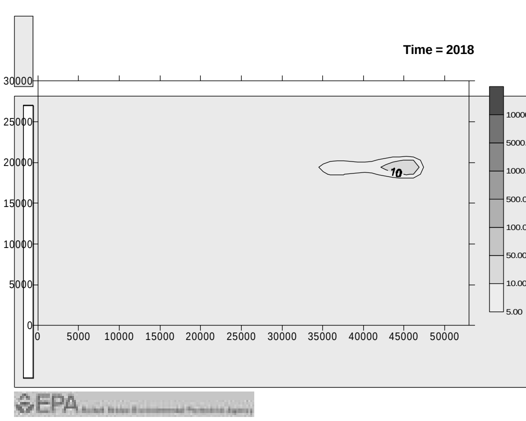
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50.00
10.00
5.00

Source and Dissolved Phase Decay Simulation Conclusions:

- Plume length and width reduced
- TCE is predicted to not reach the river at concentrations greater than 5 ug/L
- Plume reaches steady state in ~20 years after release
- Concentrations of < 5 ug/L are reached everywhere in the plume approximately year 2022

Effect of Source Control

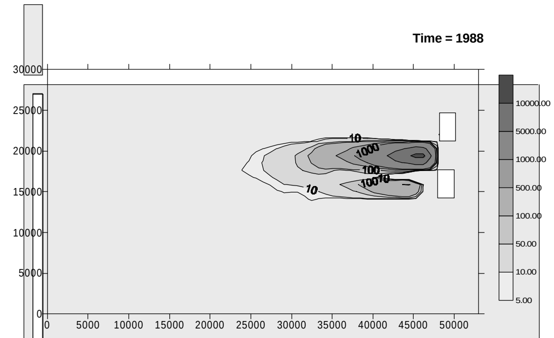
Pumping Assumptions

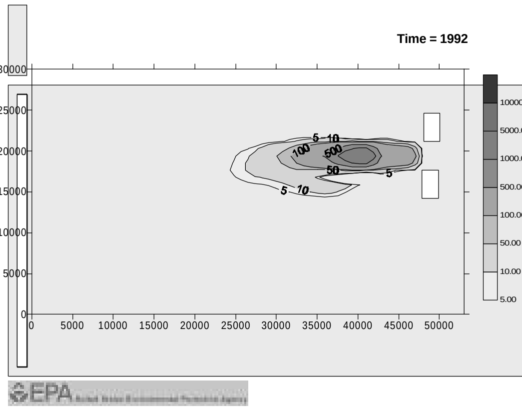
- Model assumes fully penetrating recovery wells with completely mixed TCE solute across the aquifer's saturated thickness
- Actual pumping may or may not recover TCE as predicted due to the vertical position of the well screen relative to contaminant distribution

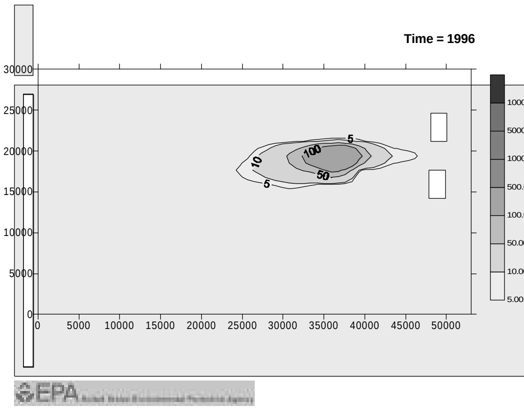
Simulated Total Control of TCE by Pumping

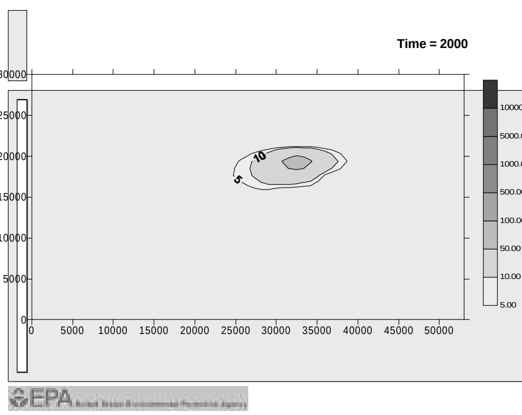
- Total control of release of TCE was simulated by eliminating the sources after 1988.
- Recovery well pumping rates were maintained at the same level as all prior simulations to simulate capture of the existing plume.

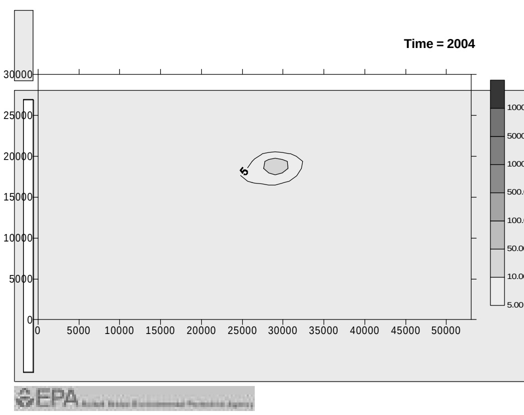
Theoretical TCE Control by Pumping

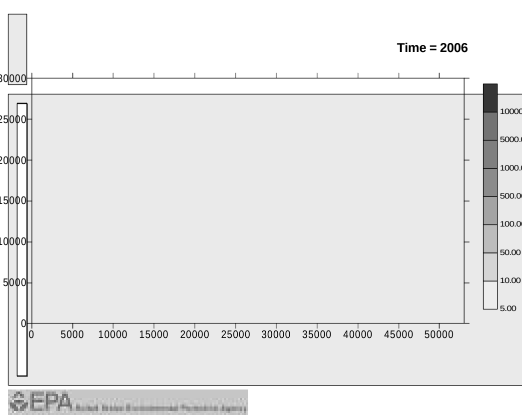












Conclusions

- Decreased concentrations along plume length are due to dissolved phase biotransformation (concentration v. distance from the source)
- Decreased concentrations at a particular monitoring location in the plume path are due to source control (concentration v. time of long-term monitoring)

Calculating Confidence Intervals on Rate Constants

John T. Wilson

Back-of-the-Envelope Prediction of the Rate of Remediation, using Simple Regression Techniques

assume:

Stable contaminant plume

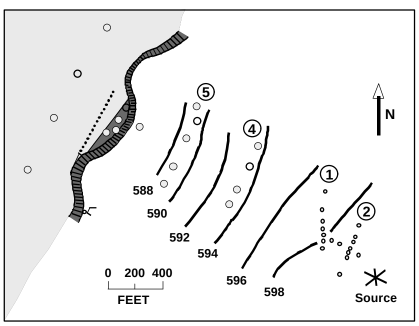
Contaminant plume contained within the foot print of geochemical tracers

Contaminant attenuation follows a first-order rate law

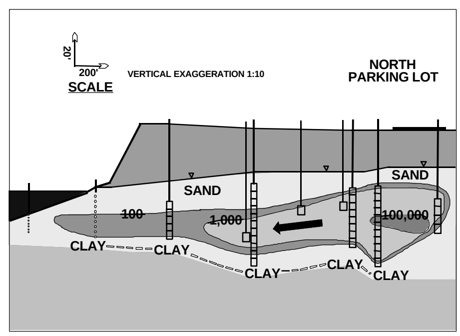
Core of the Plume has been identified

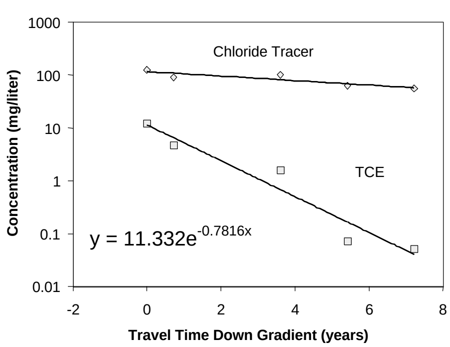
Monitoring wells available along the core center-line

St. Joseph Site



St. Joseph Site





Distance	Years	TCE ug/L	LN TCE Conc.
0	0	12.1	2.493205453
200	0.722022	4.7	1.547562509
1000	3.610108	1.6	0.470003629
1500	5.415162	0.07	-2.659260037
2000	7.220217	0.051	-2.975929646

SUMMARY OUTPUT				
Regression Statistics				
Multiple R	0.96600234			
R Square	0.93316052			
Adjusted R Squar	0.910880694			
Standard Error	0.73892431			
Observations	5			
ANOVA				
	df	*SS*		
Regression	1	22.86885714		
Residual	3	1.638027408		
Total	4	24.50688455		
	Coefficient	*Standard Erro*	*Upper 95*	*Lower 95.0%*
Intercept	2.427631492	0.526485602	4.103145223	0.752117761
X Variable 1	-0.78164541	0.120777909	-0.39727584	-1.166014981